

Product Design and Development (315367)

Model Question Paper — Set C · Model Answers

Q.1**a) Characteristics of successful product development.**

2 M

1. **Product quality** — how well the product satisfies customer needs; robust and reliable.
2. **Product cost** — manufacturing cost (tooling + cost per unit).
3. **Development time** — how quickly the development was completed.
4. **Development cost** — money spent on developing the product.
5. **Development capability** — the team became better able to develop future products.

*(Any four, ½ M each)***b) Modular product architecture.**

2 M

Modular architecture: an architecture in which each physical chunk carries out one or a few functional elements completely, and the interactions (interfaces) between chunks are well defined and simple, so a chunk can be changed without changing the others.

Examples: desktop computer (CPU, monitor, keyboard), bicycle (frame, wheels, handle, brakes), utility trailer.

*(Definition 1 M, two examples 1 M)***c) Ergonomics and its necessity.**

2 M

Ergonomics (human factors engineering) is the scientific study of the relationship between the human (user), the machine/product and the working environment, so that products and workplaces are designed to suit human abilities and limitations — “fitting the job to the man”.

Necessity: comfort and ease of use, less fatigue and errors, higher safety (fewer accidents), higher productivity and better customer acceptance of the product.

*(Definition 1 M, necessity 1 M)***d) Product life cycle and its stages.**

2 M

Product life cycle (PLC) is the sequence of stages a product passes through from its introduction in the market until its withdrawal, described by the variation of sales and profit with time.

Stages: (1) Introduction (2) Growth (3) Maturity (4) Decline.

*(Definition 1 M, stages 1 M)***e) Use value and esteem value.**

2 M

Use value: the value of the properties and qualities that make the product perform its function or service. Example: a wrist watch that shows correct time; a pen that writes.

Esteem value: the value of features or appearance that make the product attractive and give prestige / pride of ownership, beyond its use. Example: gold-plated case of a watch, branded designer pen.

(Each 1 M)

f) Voice of Customer (VOC).

2 M

VOC is the customer's own expression of his needs, wants, expectations, preferences and complaints about a product, collected in the customer's words; it is the input to QFD / House of Quality.

Methods of collecting: personal interviews, focus groups, questionnaire surveys, complaint and warranty records, observation of the product in use, social-media / online reviews.

(Meaning 1 M, any two methods 1 M)

g) Layer-by-layer approach in RP.

2 M

In rapid prototyping the 3-D CAD model is sliced into many thin horizontal cross-sections (layers, e.g. 0.05–0.3 mm). The machine builds the part by **adding material one layer at a time**, each new layer bonded to the one below, until the full 3-D part is formed (additive manufacturing). Thinner layers give better accuracy and finish but take more time.

(Principle 2 M)

Q.2

a) Design by evolution and design by innovation.

4 M

Design by evolution: the product is improved slowly over a long period through small changes to the earlier design, based on experience, failures and user feedback; no single designer is responsible for the final form. It is low-risk, but slow.

Real-world example: the bicycle — wooden running machine (dandy horse, early 1800s) → pedal-driven velocipede → high-wheel “penny-farthing” → chain-driven “safety bicycle” with equal wheels → pneumatic tyres → multi-speed geared and today's disc-brake bicycles. The plough and bullock-cart wheel are other examples.

Design by innovation: a completely new product or radical change comes from a scientific discovery, invention or new technology, rather than from slow improvement. It needs research, has high risk and high cost but can create a new market.

Real-world example: the transistor replacing the vacuum tube; the jet engine; the touch-screen smartphone replacing keypad phones; LED lamps replacing filament bulbs.

(Each concept 1 M, each example 1 M)

b) Seven-step method of concept testing.

4 M

Concept testing directly asks potential customers for their response to a description of the product concept. The seven steps are:

1. **Define the purpose of the concept test** — what questions must be answered (e.g. which concept to choose, how to improve it, likely sales).
2. **Choose a survey population** — the customers in the target market who will be asked.
3. **Choose a survey format** — face-to-face, telephone, post / e-mail, internet survey.
4. **Communicate the concept** — verbal description, sketch, photo / rendering, video, simulation, interactive multimedia, physical model or prototype.

5. **Measure customer response** — usually purchase intent on a scale: definitely would buy, probably would buy, might or might not, probably not, definitely not.
6. **Interpret the results** — estimate the market demand from the response (fraction of “definitely” and “probably” buy) and compare concepts.
7. **Reflect on the results and the process** — are the results reliable, and how can the concept or test be improved?

(Seven steps 4 M)

c) Establishing architecture of an adjustable spanner.

4 M

1. **Create a schematic of the product:** functional elements — transmit torque from hand, grip one side of nut, grip other side of nut, adjust jaw opening, hold jaw position; and flows (torque, clamping force, motion).
2. **Cluster the elements into chunks:** handle with fixed jaw (one forged body — transmits torque and holds the fixed jaw), movable jaw, worm (knurl) with pin (adjusts and holds the movable jaw).
3. **Create a rough geometric layout:** body with fixed jaw at the head; movable jaw slides in a slot of the head; worm sits in a window below the jaw, held by the pin.
4. **Identify the fundamental and incidental interactions:** fundamental — worm teeth engage rack on movable jaw; torque path from handle to jaws to nut; incidental — play / backlash between jaw and slot, wear and corrosion.

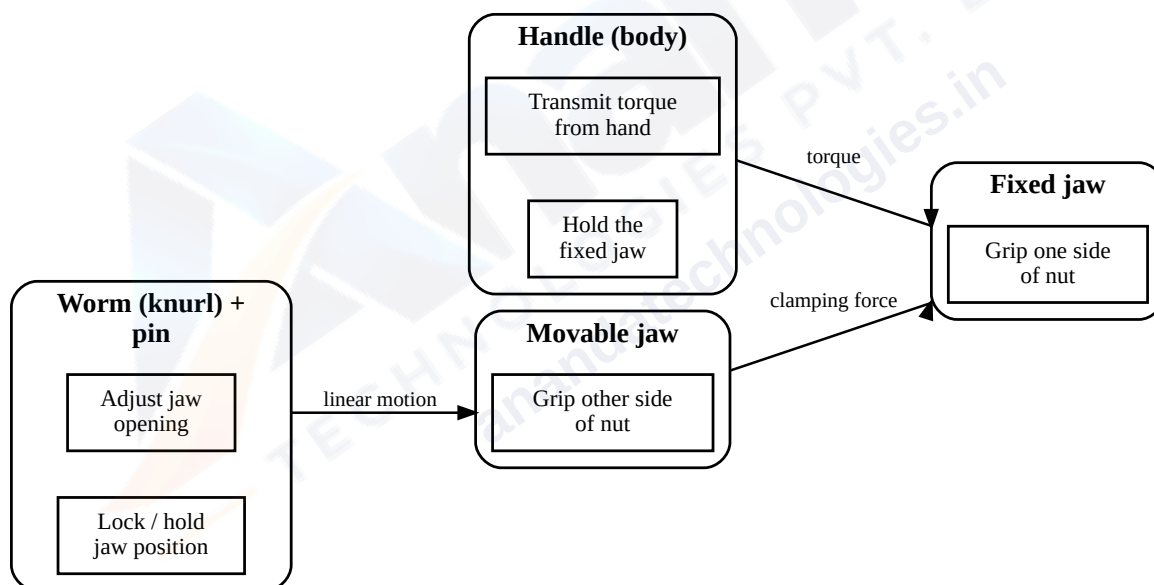


Fig.: Schematic of an adjustable spanner — functional elements clustered into chunks

Since one chunk (the body) performs several functions, the spanner has a largely **integral** architecture, which gives strength and low cost.

(Four steps 3 M, schematic 1 M)

d) Aesthetics — definition, necessity, aspects.

4 M

Aesthetics is the branch of design concerned with the appearance of a product and the pleasure it gives to the senses (sight, touch) — its beauty, style and the impression it creates in the mind of the

user.

Necessity:

- Attracts the customer at first sight and increases sales.
- Differentiates the product from competitors and builds brand identity.
- Gives an impression of quality and pride of ownership; customers pay a higher price.
- Improves user satisfaction when combined with good ergonomics.

Aspects of aesthetics: form (shape), symmetry, colour, continuity, proportion, contrast, impression and surface finish (texture).

(Definition 1 M, necessity 2 M, aspects 1 M)

Q.3

a) Control drawings and control models in industrial design.

4 M

After the final concept is selected, the industrial designer completes his work by preparing **control drawings** or **control models** (step 5 of the ID process). They document the functionality, features, size, colours, surface finishes and key dimensions of the product.

Importance:

- “Freeze” the approved appearance — a single, agreed reference for everybody.
- Communicate the design intent clearly to engineering, manufacturing, tool makers and external vendors; avoid misinterpretation.
- Used for approval by management and for customer testing.
- Form the basis for detailed engineering (CAD), tooling and costing; any later change can be checked against them.

Types of models used in ID: (i) **Soft models** — quick foam / cardboard / clay models to explore size and form; (ii) **Hard models** — wood, dense foam, plastic or metal, realistic in look and partly functional; (iii) **Appearance / control models** — exact final look and finish; (iv) renderings and 3-D CAD models.

(Meaning 1 M, importance 2 M, types 1 M)

b) Design principles for manufacturability.

4 M

1. **Minimise the number of parts** — combine parts into multifunctional parts; fewer parts mean less assembly, inventory and defects.
2. **Use standard components and materials** — cheaper, easily available, proven quality.
3. **Design parts for easy fabrication** — shapes suitable for the chosen process (uniform wall thickness for moulding, draft angles, avoid deep narrow holes).
4. **Use liberal (wide) tolerances and normal surface finish** where the function permits — tight tolerances increase cost sharply.
5. **Design for easy assembly** — top-down assembly, self-locating features, snap fits instead of screws; avoid separate fasteners.
6. **Mistake-proof (poka-yoke)** — symmetric parts or clearly asymmetric so they cannot be assembled wrongly; avoid secondary operations.

(Any four principles, 1 M each)

c) Problem identification in value engineering.

4 M

1. **Select the product / part:** choose items with high cost, high volume, many customer complaints, or low profit (Pareto / ABC analysis of cost).
2. **Collect information:** drawings, specifications, quantity, cost break-up of material, labour and overheads, and customer requirements.
3. **Ask the basic VE questions:** What is it? What does it do? What must it do? What does it cost? What is it worth? What else will do the job? What will that cost?
4. **Define functions:** express every function as a verb + noun (e.g. “transmit torque”), classify as basic or secondary.
5. **Find cost and worth of each function:** worth = lowest cost to reliably perform the function; value index = worth / cost.
6. **Identify the problem area:** functions / parts with low value index (cost much greater than worth) and unnecessary secondary functions are selected as problems for the creative phase.

(Any four steps with explanation, 1 M each)

d) FDM 3-D printer.

4 M

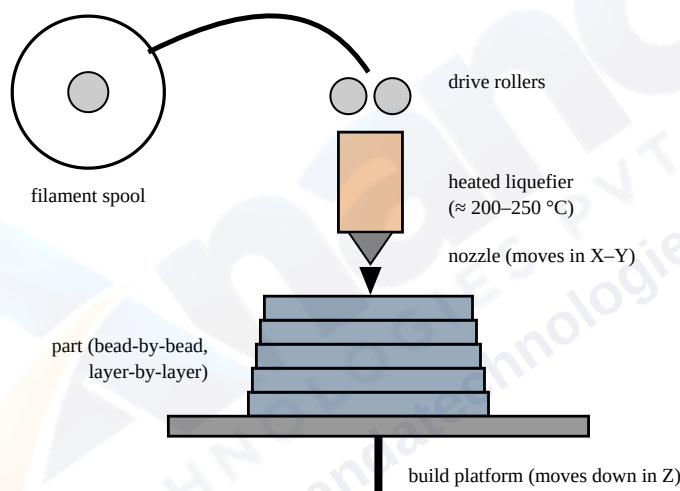


Fig.: Fused Deposition Modelling (FDM) — schematic

Construction: filament spool, drive (feed) rollers, heated liquefier with nozzle (extrusion head) moving in X–Y, build platform moving in Z (often heated), and a controller.

1. The CAD model is sliced into layers (0.1–0.3 mm) and tool paths (G-code) are generated.
2. Thermoplastic filament (PLA, ABS) is pushed by the drive rollers into the heated liquefier, where it melts.
3. The nozzle extrudes a thin bead of semi-molten plastic and traces the outline and fill of the first layer on the platform; the bead cools and solidifies, bonding to the material below.
4. The platform moves down (or the head moves up) by one layer thickness and the next layer is deposited. Supports are printed for overhangs (same or soluble material).
5. After completion the part is removed and supports are broken away; finishing (sanding) if required.

(Sketch 2 M, working 2 M)

Q.4

a) Component standardization.

4 M

Component standardization is the use of the **same component or chunk in several different products** (or several times in one product) instead of designing a new part each time. It is made possible by a modular architecture with standard interfaces.

Examples:

- Standard fasteners (M6, M8 bolts and nuts), ball bearings (e.g. 6205) and O-rings used in many machines.
- AA / AAA cells, USB-C chargers used across many electronic products.
- The same engine or gearbox used in several car / motorcycle models of a company; same headlamp or mirror in different models.
- Standard tyres and rims; the same motor in several mixer-grinder models.

Advantages: lower cost (higher volume, better price from suppliers), proven quality and reliability, smaller inventory and fewer part numbers, shorter development time, easy availability of spares and service.

(Meaning 1 M, examples 1½ M, advantages 1½ M)

b) Concept development process (front-end activities).

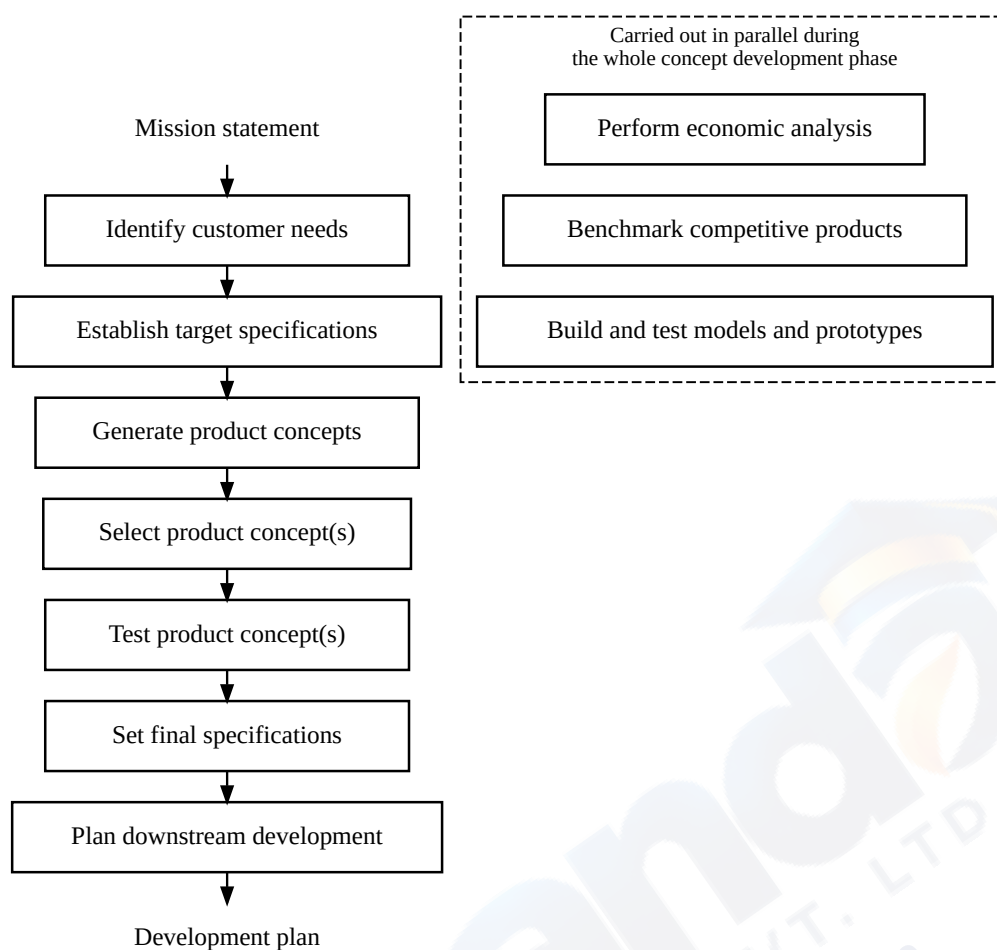


Fig.: Front-end activities (phases) of the concept development process

1. **Identify customer needs** — understand needs and communicate them to the team.
2. **Establish target specifications** — precise, measurable description of what the product has to do.
3. **Generate product concepts** — explore physical, working and form solutions (five-step method).
4. **Select product concept(s)** — screening and scoring against criteria.
5. **Test product concept(s)** — get customer response.
6. **Set final specifications** — revise targets after the concept is fixed.
7. **Plan downstream development** — detailed schedule, strategy and resources.

Economic analysis, benchmarking of competitive products and building/testing of models and prototypes go on in parallel during the whole phase. Output: development plan.

(Flow chart 2 M, explanation 2 M)

c) House of Quality — structure and linking complaints to technical requirements.

4 M

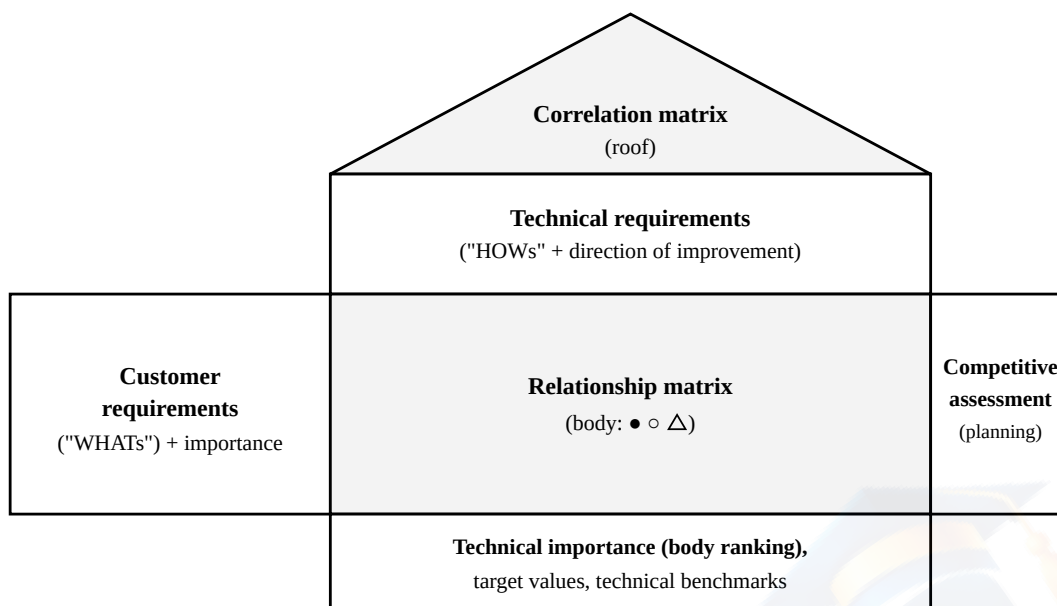


Fig.: Structure (rooms) of the House of Quality

1. **Collect customer complaints (VOC)** and convert each into a positive customer requirement (WHAT); e.g. “ceiling fan wobbles” → “runs smoothly”. Put them on the left wall with importance (1–5).
2. **Write technical requirements (HOWs)** that are measurable and can satisfy the complaints, e.g. “blade balance (g·mm)”, with direction of improvement.
3. **Fill the relationship matrix (body)** with ● 9, ○ 3, △ 1 to link each complaint to the technical requirements; an empty row shows a complaint not covered.
4. **Fill the roof** (correlations among HOWs), the **competitive assessment** (our product vs competitors as rated by customers) and calculate **technical importance** = $\Sigma \text{importance} \times \text{weight}$ in the basement; set target values.

Thus every complaint is traced to the engineering characteristics that must be changed, and the most important ones get priority.

(Sketch 2 M, explanation 2 M)

d) FDM vs SLA vs SLS.

4 M

Point	FDM	SLA	SLS
Raw material	Thermoplastic filament (PLA, ABS, PETG, nylon)	Liquid photopolymer resin	Polymer powder (nylon PA12/PA11, TPU); metal powders in metal versions
Principle	Molten plastic extruded through a heated nozzle, bead by bead	UV laser cures (solidifies) resin layer by layer	Laser sinters (fuses) powder particles layer by layer
Layer thickness (typical)	0.1 – 0.3 mm (coarse)	0.025 – 0.1 mm (very fine)	≈ 0.1 mm

Resolution / accuracy (typical)	Lowest; about $\pm 0.2 - 0.5$ mm	Highest; about $\pm 0.05 - 0.1$ mm	Good; about ± 0.3 %
Support structure	Needed for overhangs	Needed; removed after printing	Not needed — loose powder supports the part
Surface finish	Rough, layer lines visible	Very smooth	Slightly grainy / matt
Applications	Concept models, jigs and fixtures, education, hobby	Dental and jewellery patterns, detailed prototypes, small precise parts	Functional prototypes, end-use parts, snap fits, ducts, complex shapes

(Any four points, 1 M each)

e) Need and importance of QFD.

4 M

QFD (Quality Function Deployment) is a structured, customer-driven planning method that translates the voice of the customer into technical requirements at each stage of product development — design, parts, process and production planning.

- 1. Customer focus:** design decisions are based on real customer needs and their importance, not on assumptions.
- 2. Prioritisation:** technical importance (body ranking) shows where to spend effort and money first.
- 3. Fewer design changes, shorter development time and lower cost:** problems are solved at the planning stage rather than after tooling.
- 4. Identifies trade-offs** between technical requirements (roof) early.
- 5. Better team work and communication** between marketing, design, manufacturing and quality; one common document.
- 6. Competitive benchmarking** and higher customer satisfaction; the HoQ is a record for future products.

(Meaning 1 M, any three points 3 M)

Q.5

a) Determining PLC of a smartphone model.

6 M

Procedure:

1. Collect the yearly (or quarterly) sales of the model from company / market-research data, and also price, profit and number of competing models.
2. Calculate the growth rate of sales for each period.
3. Plot sales vs time and compare with the standard PLC curve.
4. Classify each period into a stage using the growth rate and market behaviour; decide the strategy (new variant, price cut, phase-out).

Example — a mid-range smartphone model (assumed data for illustration only):

Year	Sales (lakh units, assumed)	Growth over previous year	Stage
2021	0.8	—	Introduction

2022	4.2	+425.0%	Growth
2023	6.1	+45.2%	Growth
2024	6.4	+4.9%	Maturity
2025	5.7	-10.9%	Decline
2026	3.1	-45.6%	Decline

Rule used to fix the stage: sales still below 20 % of the peak and rising → Introduction; growth $\geq$ 15 % per year → Growth; growth between -5% and $+15\%$ (sales levelled) → Maturity; sales falling more than 5% per year → Decline.

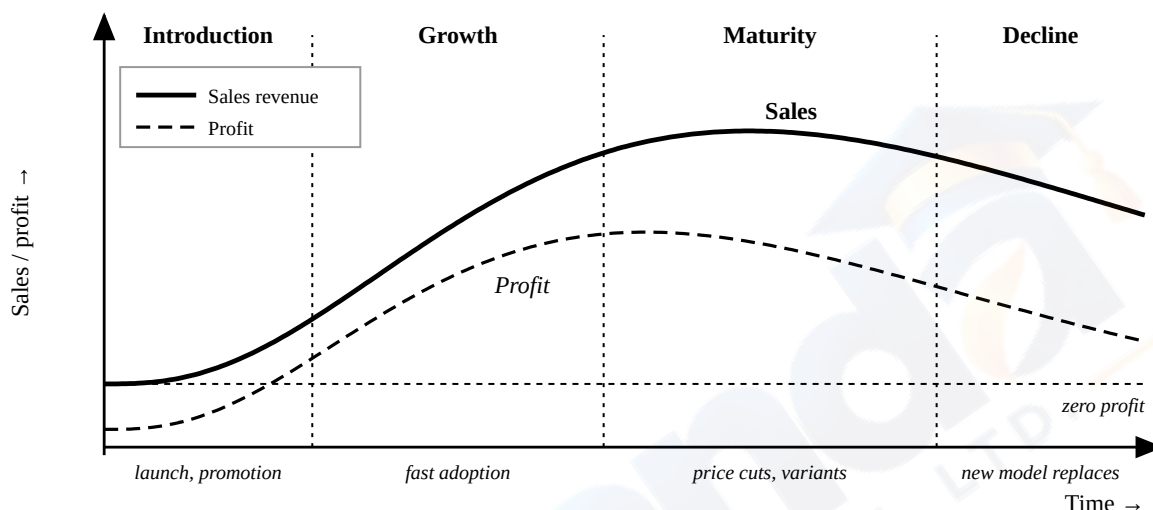


Fig.: PLC of a smartphone model

Result: the model passed through introduction (2021), growth (2022–2023), maturity (2024) and is now in the **decline** stage (2026: -45.6% fall). Smartphone models have a short PLC (2–4 years) because new models with better cameras and processors are launched every year. Strategy: reduce price, clear stock, and launch the successor model.

(Procedure 2 M, data/curve 3 M, conclusion 1 M)

b) Types of rapid prototypes and planning for prototyping.

6 M

Type	Purpose	Typical form	Example
Proof-of-concept prototype	Shows that the basic idea / working principle is feasible; answers “will it work?”	Crude, partial, made quickly from available parts; appearance ignored	Breadboard circuit + 3-D printed cam to prove an automatic pill dispenser idea
Looks-like prototype	Shows the final appearance — shape, size, colour, finish, ergonomics; used for customer feedback and marketing	Non-working model (SLA / foam / painted print)	Painted SLA model of a new mixer-grinder body
Works-like prototype	Demonstrates the actual function and performance; used for testing	Working mechanism / electronics; appearance not final	Working drone with open frame to test flight time

Planning for prototyping (four steps):

1. **Define the purpose:** learning, communication, integration or milestone.
2. **Establish the level of approximation:** physical or analytical; the simplest prototype that serves the purpose.
3. **Outline an experimental plan:** variables, test protocol, measurements, analysis.
4. **Create a schedule for procurement, construction and testing:** dates for parts ready, first test and results.

Example: drone propeller-guard drop test — purpose: choose guard material that survives a 2 m fall; approximation: correct guard geometry and material only; plan: 3 materials × 2 rib designs dropped 10 times each; schedule: 3 weeks.

(Three types 3 M, planning steps 3 M)

c) VEJP phases — gas-stove lighter.

6 M

The **Value Engineering Job Plan (VEJP)** is the organised sequence of phases used by the VE team to remove unnecessary cost while keeping the required functions.

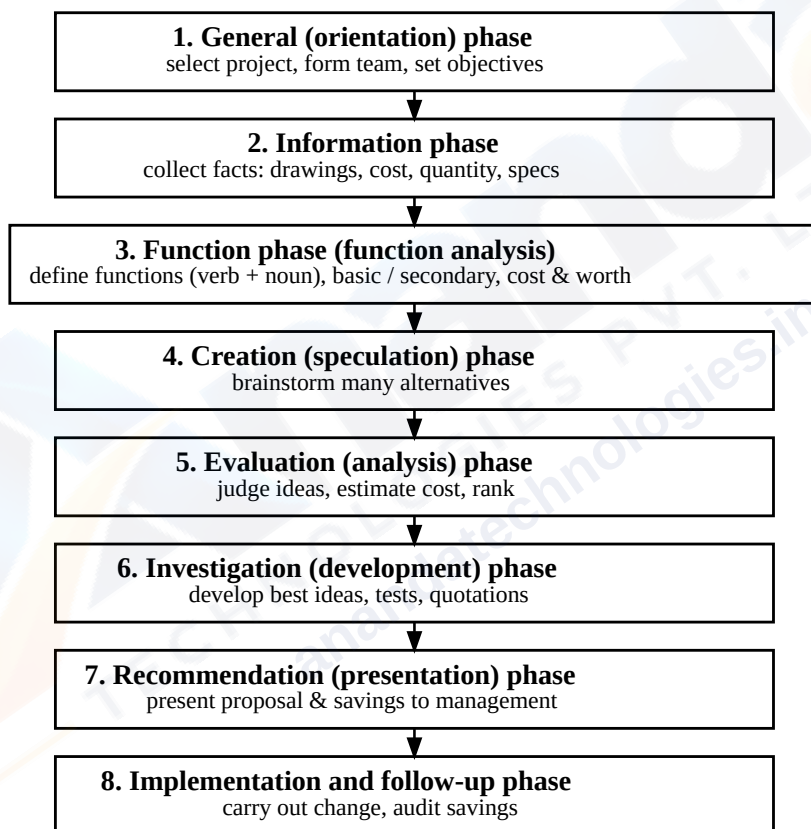


Fig.: Value Engineering Job Plan (VEJP) — phases

1. **General / orientation phase:** select the product or part (high cost, high volume, many complaints), form a team, fix objectives and target saving.
2. **Information phase:** collect all facts — drawings, specifications, quantities, cost break-up, customer complaints; ask “What is it? What does it cost?”.
3. **Function phase:** define each function in two words (verb + noun), separate basic and secondary functions, find the cost and worth of each function (value index).

4. **Creation (speculation) phase:** generate many alternative ways to perform the function — brainstorming, SCAMPER; no criticism at this stage.
5. **Evaluation phase:** screen and rank the ideas for cost, feasibility and performance; select the best few.
6. **Investigation (development) phase:** develop the selected ideas in detail — drawings, tests, supplier quotations, cost estimates.
7. **Recommendation (presentation) phase:** present the proposal with savings, investment and benefits to management for approval.
8. **Implementation and follow-up:** carry out the approved change, monitor the actual savings and quality.

Example — gas-stove (piezo) lighter (cost and worth assumed):

Component	Function (verb + noun)	Basic / Secondary	Cost ₹	Worth ₹	Value index = Worth / Cost	Saving potential ₹
Die-cast body	Enclose parts	Secondary	48	20	0.42	28
Piezo unit	Generate spark	Basic	55	50	0.91	5
Brass nozzle tube	Guide spark	Basic	30	25	0.83	5
Push button + spring	Actuate piezo	Secondary	12	10	0.83	2
Chrome plating	Improve look	Secondary	15	5	0.33	10

Total cost = ₹160; total worth = ₹110; overall value index = $110/160 = 0.69$. The component with the lowest value index (**Chrome plating**, 0.33) is the first target for value improvement.

Creation / evaluation: replace the die-cast body by an ABS moulded body with colour in material, so chrome plating is eliminated. **Recommendation:** cost of body + plating falls from ₹63 to about ₹22; basic function “generate spark” is unchanged.

(Phases 5 M, example 1 M)

Q.6

a) Identifying customer needs — school bag.

6 M

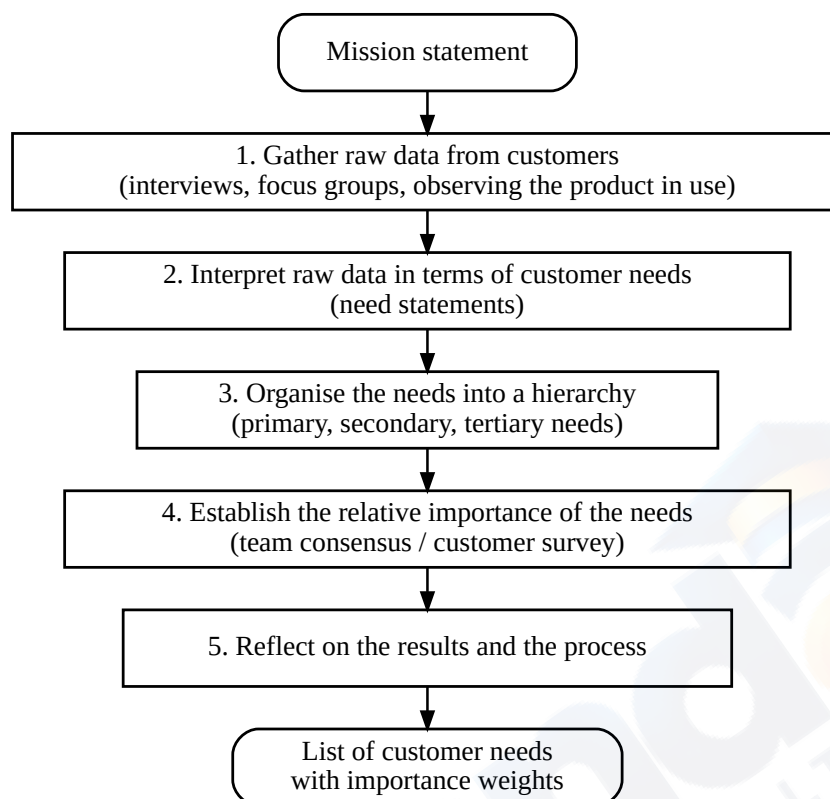


Fig.: Five steps of identifying customer needs

1. Data collection from customers: interviews with students and parents at schools, a focus group of parents, and **observation** of children carrying bags (how they lift, carry on one shoulder, etc.). Customer statements are noted exactly as said (raw data).

2. Interpret the raw data as need statements (what the bag must do, positive, attribute of the product).

3. Organise the collected data into a hierarchy — primary needs (comfort, capacity, durability, weather protection, look) with secondary needs under each (affinity grouping on cards).

4. Establish relative importance by a survey of parents/students rating each need from 1 (not important) to 5 (critically important).

Primary need	Secondary need statement	Importance (1–5)	Raw data source
Comfort	The bag is comfortable to carry for 30 minutes.	5	“My shoulders pain after walking to school.”
Comfort	The bag load is shared on both shoulders and the back.	4	Observation: children carry on one shoulder.
Capacity	The bag holds all books of one day plus a lunch box.	5	“Tiffin does not fit with books.”
Capacity	The bag keeps the water bottle separate.	3	“Bottle leaks on books.”

Durability	The bag straps do not tear for at least two years.	4	“Strap stitching came out in 3 months.”
Weather	The bag keeps books dry in rain.	4	“Books got wet in monsoon.”
Look	The bag looks attractive to children.	2	“I want a bag with my favourite colour.”

5. Reflect: check that both users (students) and buyers (parents) were covered. The design team concentrates first on the needs rated 5 — comfortable carrying (padded straps, back panel) and enough capacity.

(Steps 3 M, example with hierarchy and importance 3 M)

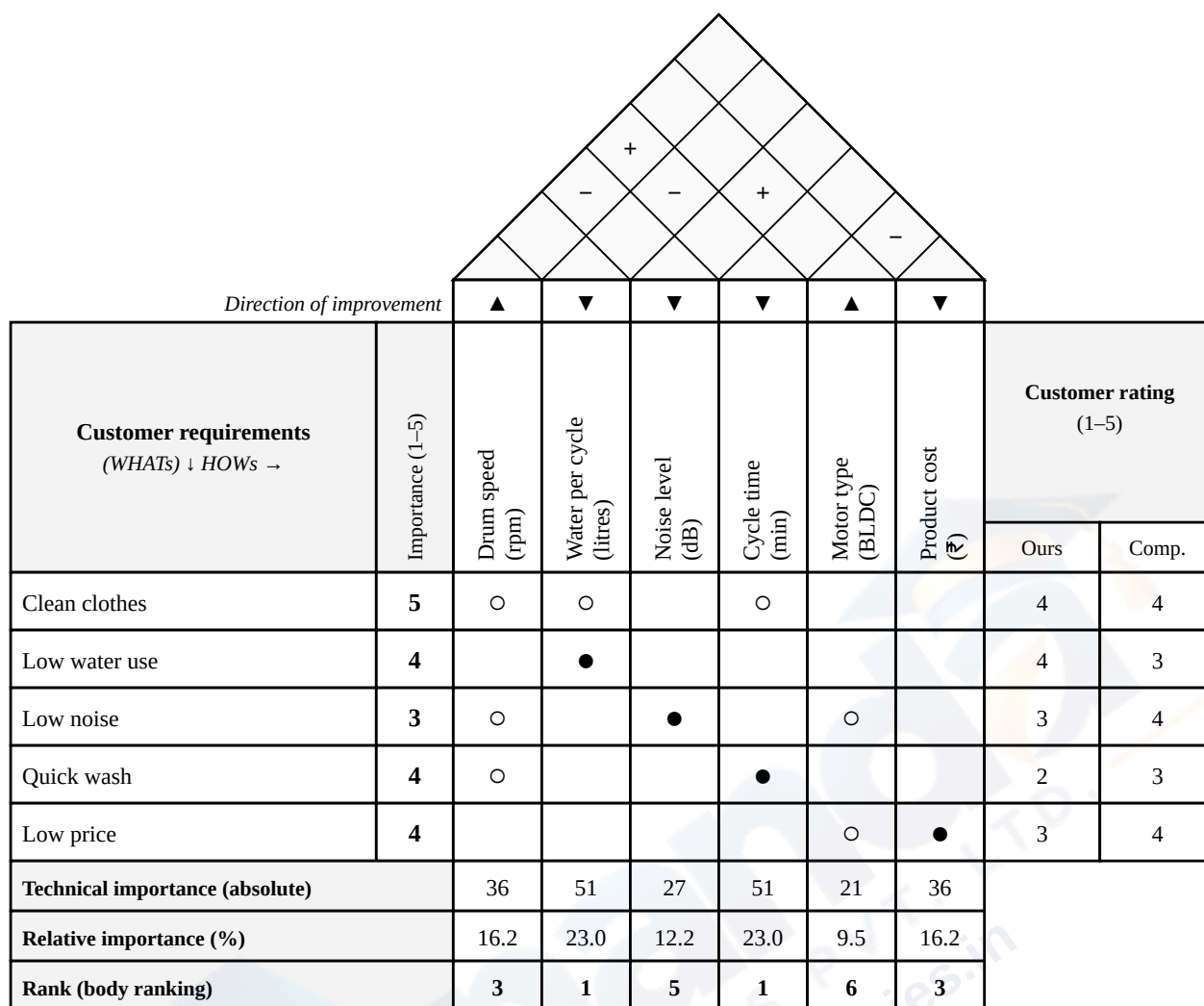
b) House of Quality — washing machine with roof ranking.

6 M

The House of Quality relates customer requirements to technical requirements; the **roof** shows the correlation between technical requirements and helps to identify trade-offs.

1. List customer requirements (WHATs) on the left wall and give each an importance rating (1 = low, 5 = very high).
2. List measurable technical requirements (HOWs) on the ceiling with the direction of improvement (▲ / ▼ / ⊙).
3. Fill the relationship matrix (body): ● strong = 9, ○ medium = 3, △ weak = 1.
4. Fill the roof (correlation matrix) to show how technical requirements support (+) or conflict (–) with each other.
5. Compare our product with a competitor (customer rating 1–5) in the right wall.
6. Body ranking: technical importance of each HOW = Σ (importance $\times$ relationship weight); convert to % and rank.

Front-loading washing machine



Relationship: ● strong = 9, ○ medium = 3, △ weak = 1. ▲ maximise, ▼ minimise, ⊙ target.

Roof: ++ strong positive, + positive, - negative, -- strong negative correlation.

Fig.: House of Quality — Front-loading washing machine

Calculation of technical importance (body ranking):

Technical requirement	Σ importance × weight	Relative %	Rank
Drum speed (rpm)	$5 \times 3 + 3 \times 3 + 4 \times 3 = 36$	16.2	3
Water per cycle (litres)	$5 \times 3 + 4 \times 9 = 51$	23.0	1
Noise level (dB)	$3 \times 9 = 27$	12.2	5
Cycle time (min)	$5 \times 3 + 4 \times 9 = 51$	23.0	1
Motor type (BLDC)	$3 \times 3 + 4 \times 3 = 21$	9.5	6
Product cost (₹)	$4 \times 9 = 36$	16.2	3

Result: the design team should give first priority to **Water per cycle (litres)** (rank 1), then **Cycle time (min)**.

Roof ranking (trade-offs): negative correlations exist between Drum speed (rpm) ↔ Noise level (dB); Water per cycle (litres) ↔ Cycle time (min); Motor type (BLDC) ↔ Product cost (₹). For

each such pair, improving one makes the other worse, so a balanced target value must be chosen (or a new technology used).

Positive correlations: Noise level (dB) ↔ Motor type (BLDC); Drum speed (rpm) ↔ Cycle time (min) (improving one helps the other).

(Requirements 1 M, matrix 2 M, roof ranking 1 M, technical importance 2 M)

c) Concept screening — mobile-phone holder for motorcycle.

6 M

Concept screening (developed by Stuart Pugh) is a quick, approximate method to narrow the number of concepts. Concepts are rated relative to a **reference concept** using + (better than), 0 (same as) and – (worse than).

Steps: 1) prepare the selection matrix — criteria from customer needs, concepts, reference; 2) rate the concepts (+, 0, –); 3) rank the concepts by net score; 4) combine and improve the concepts; 5) select one or more concepts; 6) reflect on the results and the process.

Selection criteria	A: Rubber-band clamp (reference)	B: Spring-loaded 4-corner grip	C: Zip pouch with clear window	D: Magnetic mount	E: Quad-lock with case
Holds phone firmly on rough road	0	+	+	–	+
Easy one-hand mounting	0	+	0	+	+
Fits many phone sizes	0	+	+	+	–
Protects phone from rain	0	0	+	0	0
Low cost	0	0	0	–	–
Easy to manufacture	0	0	0	0	–
Sum +’s	0	3	3	2	2
Sum 0’s	6	3	3	2	1
Sum –’s	0	0	0	2	3
Net score	0	+3	+3	0	-1
Rank	3	1	1	3	5

Result: the concepts with the highest net scores — **B: Spring-loaded 4-corner grip, C: Zip pouch with clear window** — are selected for further development (concept scoring). Concept D (magnetic mount) may be improved by adding a safety strap; concept E can be dropped because it needs a special case for every phone model.

(Meaning and steps 2 M, matrix 3 M, selection 1 M)

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